DOE GENOMICS:GTL
SYSTEMS BIOLOGY FOR ENERGY AND ENVIRONMENT
OFFICE OF SCIENCE
U.S. DEPARTMENT OF ENERGY

DOE OFFICE OF SCIENCE GENOME PROGRAMS

Merging Genomics, Computing, and New Bioscience Research Infrastructure to Harness Microbial Capabilities for U.S. Energy Independence

A World of Microbes for DOE Missions

Microbes are the foundation for life on earth.

DOE Office of Science genome research programs use DNA sequences of microbes to launch large-scale investigations into the wide-ranging and complex biochemical abilities of these organisms. The knowledge gained can provide a foundation for energy and environmental solutions.

Biofuels

Understand microbes and their components to enable optimized systems for producing biofuels such as cellulosic ethanol and hydrogen.

2025
Efficiently convert plant cellulose to ethanol

2050
Mobilize biohydrogen-based industry

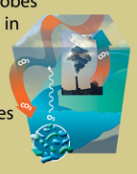
Cleanup

Explore how microbes function in the earth's subsurface and how they impact contaminant fate to develop better assessment and remediation strategies.

2020
Save billions of dollars in toxic waste cleanup and disposal

Climate Stabilization

Determine how microbes impact carbon cycling in ocean and terrestrial ecosystems to develop better ways to assess global carbon sequestration strategies and climate impacts.



2040
Help stabilize atmospheric carbon dioxide to counter global warming

Payoffs for the Nation

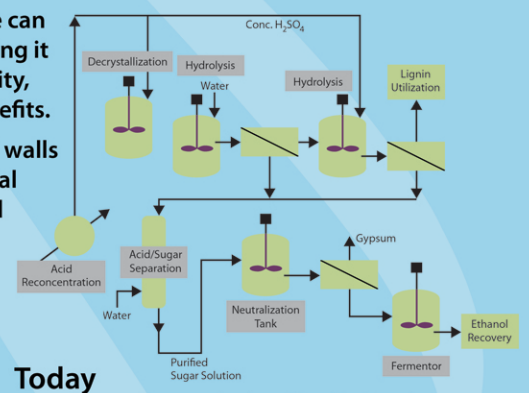
A Closer Look at Bioethanol

Using microbes to make bioethanol an efficient, low-cost alternative to oil

Biofuels made from plant cellulose can provide alternatives to oil, displacing it as a transportation fuel with security, economic, and environmental benefits.

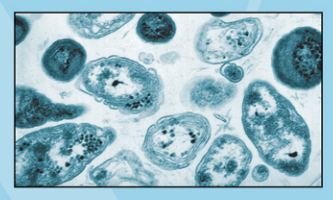
Lignocellulose makes up plant cell walls and is the most abundant biological material on earth. The strong, rigid nature of cellulose, however, makes it difficult (and expensive) to break down to sugars for fermentation to ethanol. Many microbes and fungi are sources of enzymes called cellulases that can degrade cellulose into its simpler components.

Natural and integrated microbial enzyme systems can replace current catalysts and enable smaller-scale and more cost-effective and energy-efficient processes. At right are some of the research goals and challenges for optimizing the use of microbes or their enzymes in the conversion of biomass (plant materials) to cellulosic ethanol.



Today
we use fermentation to make ethanol from food starch—an ultimately limited resource. Though lignocellulose is plentiful, current processes to make cellulosic ethanol are complex and expensive.

Tomorrow
we want to integrate production processes in microbes for converting cellulose from high-yield crops to ethanol and other fuels.



Science Goals	Challenges
Screen databases to find and analyze natural variants of microbial cellulases and other enzymes	*There are thousands of variants of all enzymes, millions of genes, and thousands of microbial species and associated functions.*
Modify and analyze variants to determine important characteristics needed for optimal enzymatic activity	*Potentially thousands of modified enzymes must be produced and analyzed, and hundreds of regulatory processes and interactions must be monitored.*
Model and simulate cellulase, sugar transport, and fermentation processes and systems	*Required are modeling and simulating at multiple levels (molecular, cellular, and community), incorporating numerous interconnected activities, such as signaling, sensing, metabolism, and transport.*
Integrate multiple processing steps into single microbes or stable cultures of consortia of microbes	*There are hundreds of metabolic, regulatory, and other interconnected pathways to coordinate.*

Genomics:GTL Research Program

Building on the successes of the DOE-initiated Human Genome Project

The GTL scientific program and its four planned user facilities leverage DOE strengths in genomics, computing, technology development, and multidisciplinary teaming to deliver timely applications needed for important biotechnology advances to support energy independence.

The ultimate scientific goal of the GTL program is to develop a deep understanding of living microbes and their natural communities that supports the development of precise computer models for predicting the behavior of these living systems.

Computer models are a necessary prelude to using microbes and their capabilities safely and effectively for robust applications that meet national needs.

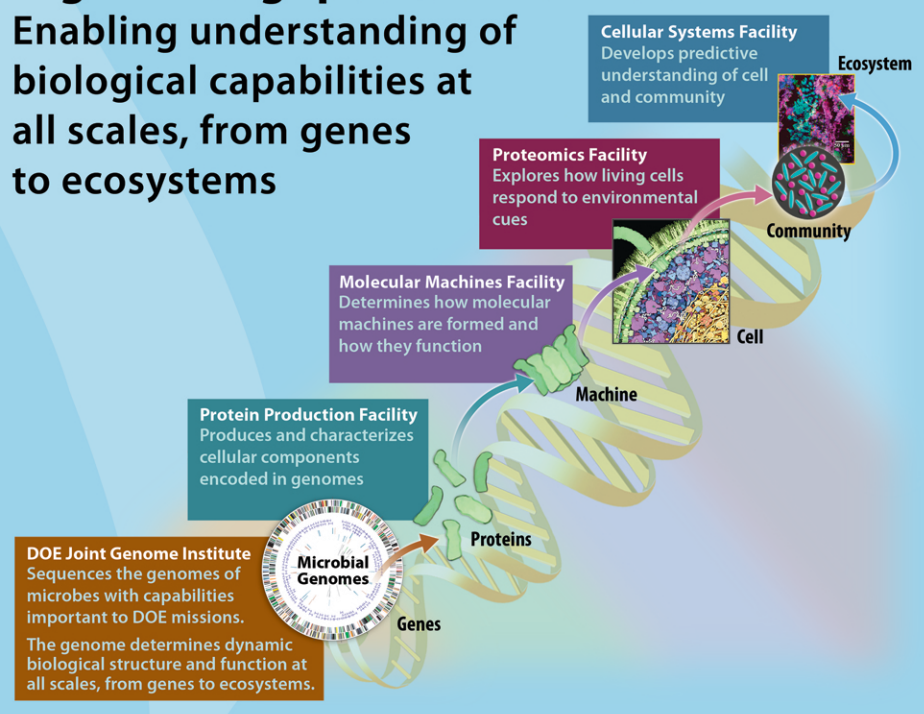
These capabilities will allow frontier science to be incorporated more directly into useful applications and will reduce time and costs between discovery and use.

GTL provides the scientific foundation for industrial applications and public policy:

- **Applications technologies: Biofuels production and bioremediation technologies**
- **Policy-support products: Climate and economic models to support assessments of energy and carbon-sequestration strategies**

High-Throughput User Facilities

Enabling understanding of biological capabilities at all scales, from genes to ecosystems



The Basics: From DNA to Living Cells to Communities

- The genome is an organism's complete set of DNA.
- DNA contains genes whose sequences specify how and when to build proteins.
- Proteins perform most essential life functions, often working together as molecular machines.
- Molecular machines interact through complex, interconnected pathways and networks to make the working cell come alive.
- Communities of cells are associations of microbes (each a single cell) working together in a particular environmental niche.

DOEGenomesToLife.org

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